

PNAA 2-747  
121 40041

**UNDERSTANDING CLAY RECOGNITION AND PROCESSING**

by  
**Miska Petersham**

**Technical Reviewers:**  
**Daniel Rhodes**  
**Gerald Rowan**

**Published by:**  
**Volunteers in Technical Assistance (VITA)**  
**1815 North Lynn Street, Suite 200**  
**Arlington, Virginia 22209 USA**  
**Telephone 703/276-1800**  
**Cable VITAINC**  
**Telex 440192 VITAU**

## PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Leslie Gottschalk and Maria Giannuzzi as editors, Julie Berman handling typesetting and layout, and Margaret Crouch as project manager.

Miska Petersham, the author of this VITA Technical Paper and a second one, "Understanding The Small-Scale Clay Products Enterprise," has worked in the field of ceramics for many years. He is also a designer in glass and wood and a wood carver, and has considerable experience in these fields in developing countries. Reviewers Daniel Rhodes and Gerald Rowan are also experts in clay and ceramics. Daniel Rhodes is a professor emeritus at Alfred University, New York, in ceramics. He is the author of four books on ceramics, and has experience with pottery design, glazes, kilns, molds, clay refining, etc. Gerald Rowan is the chairman of the art department at Northampton Community College, Pennsylvania. He has a wide knowledge of ceramics, clay, brick making, kiln building, glazes, owner made equipment, etc.

VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry Service, a specialized documentation center, and a computerized roster of volunteer technical consultants; manages long-term field projects; and publishes a variety of technical manuals and papers. For more information about VITA services in general, or the technology presented in this paper, contact VITA at 1815 North Lynn Street, Suite 200, Arlington, Virginia 22209 USA.

# UNDERSTANDING CLAY RECOGNITION AND PROCESSING

By VITA Volunteer Miska Petersham

## I. ABOUT CLAY IN GENERAL

Clay occurs naturally almost everywhere in the world and is formed by the action of **weathering** on several kinds of rocks. This process takes many thousands of years, but it happens wherever the rocks are exposed to the natural forces of wind, water, frost, etc. The rocks change very slowly in both physical and chemical ways. Physically, they break down into smaller and smaller bits; chemically, elements are added and taken away. After a long, long time, some of the rock changes to clay. The longer the geological period of time, the more clay is formed. There are several different kinds of clay minerals and most clay deposits contain more than one kind. "Clay" is the general term that is used for all the clay minerals. Some of these clay minerals or clays are of greater use to the potter than others. It takes difficult laboratory tests to determine just which clay minerals are present in a particular clay. As practical potters, however, we are more concerned with how the clay works in use, rather than exactly what is in it.

All of these clay minerals are a variation of the one called Kaolin. Kaolin is the most pure and is a hydrous silicate of alumina. This means that it contains aluminium oxide, silicon oxide, and water linked chemically. The other clay minerals often contain more water and also have some impurities, such as potassium, sodium, etc.

Clays are made up of many small, flat particles. The size of these particles affects the way the clay behaves. If the clay has been carried long distances by water, the particles are smaller and smoother so that the resulting clay is usually more plastic.

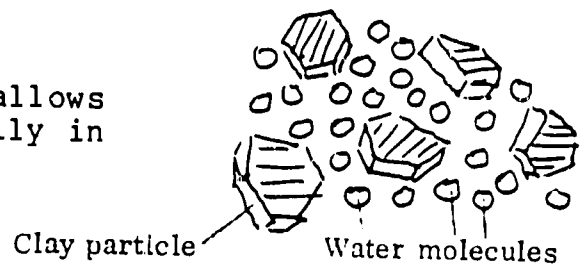
In a very simplified way, Figures 1 through 7 show what happens when wet clay is dried. The clay particles and water molecules are actually too small to be seen, except in a special microscope.

---

Note: Terms in bold face are defined in the glossary in the back of this paper.

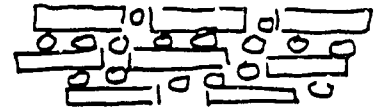
### Figure 1. Slip

Note: Adding enough water allows clay particles to move easily in any direction.



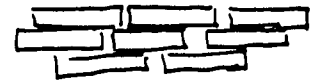
### Figure 2. Plastic Clay

Note: With less water, clay particles slide over each other with some resistance.



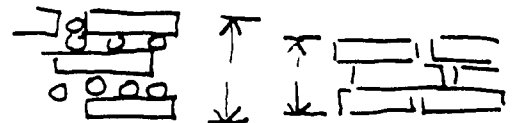
### Figure 3. Dried Clay (Greenware)

Note: Adding no water allows clay particles to touch each other and prevents them from sliding.



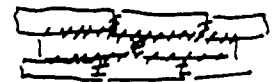
### Figure 4. Clay Shrinkage

Note: Water dries out and clay particles move together, causing shrinkage. Shrinkage can vary between 10 and 25 percent.



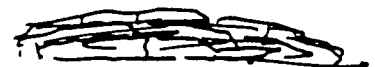
### Figure 5. Binding Clay Particles Together

Note: Heating over 800 degrees Centigrade causes the edges of particles to melt and form glass. This acts like glue and binds the particles together.



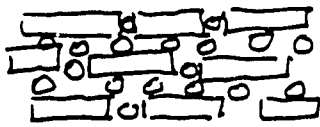
### Figure 6. Heating Clay Beyond Maturation

Note: Heating clay beyond the maturing point melts it to glass and causes it to sag or puddle.

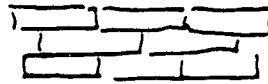


**Figure 7. Clay Shrinkage Phases.**

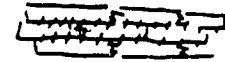
Note: shrinkage occurs twice: first, when clay is dried, and again, when it is fired.



Plastic



Dry



Fired

When clay is fired at 800 degrees Centigrade or more, it will no longer slake (absorb water) but remains hard and permanent because of the glass that is formed.

The most common clay minerals are Kaolin, Illite, Montmorillonite, and Halloysite (or disordered Kaolin).

Clays from the temperate zones are weathered slowly from feldspathic rock, which is common in these areas. Because these clays have been slowly weathered, they tend to consist of the more stable clay minerals (Kaolin) and to be uniform in content. Thus, temperate clays are most often Kaolin alone or with small additions of Illite and/or Montmorillonite. Owing to the longer geological time period, temperate clays are often transported long distances by water, thereby collecting impurities and being ground finer. Temperate clays, therefore, represent a rather orderly progression from pure Kaolin, weathered on site (primary) to common surface clays carried long distances by water (secondary). Table 1 presents some well-known kinds of temperate clay.

**Table 1. Some Established Categories of Temperate Clays**

Transfer	Material	Color	Plasticity	Firing Term	Degrees Centigrade
None to Short	Kaolin	White	Low	High	1300 - 1400
Short to Long	Ball Clay	Buff-White	High	Medium High	1250 - 1300
Medium to Short	Fire Clay	Buff-Gray	Med	Medium High	1250 - 1300
Long	Earthenware	Buff-Red	High	High	1000 - 1100

Tropical clays are of volcanic origin and are quite different. They are weathered relatively quickly because of the high heat, humidity, and acidic conditions. Because of the shorter geological period and less movement physically, they are often a mixture of several clay minerals. These usually are the less stable ones. The clays are younger and contain more Illite, Montmorillonite, and Holloysite in relation to Kaolin. Tropical clay deposits vary greatly in constituents and physical characteristics over short distances. They do not show the orderly progression of temperate clays because the mixtures are more varied, and travel-mixing has seldom taken place. Almost all contain iron as a basic constituent, since the parent rock is largely basaltic, with a high iron content. They also often contain a high proportion of parent rock.

Tropical clays have maturing temperatures of from under 1000 degrees Centigrade to over 1400 degrees Centigrade; that for most falls between 1100 degrees Centigrade and 1200 degrees Centigrade. Plasticity is often medium to high, owing to the presence of Montmorillonite. Shrinkage is high and the color is usually dark buff to red. It is impractical to relate them to temperate clay categories or to seek a pattern by which to set up a local category system.

## II. USING TROPICAL CLAYS

Due to the presence of clay minerals other than Kaolin, there is excess chemical water in the clay. This water is given off at different temperatures depending upon the minerals present; some can be given up as late as 1000 degrees Centigrade. The water is often released rather suddenly causing potential problems. For best results:

- Dry pots slowly and evenly.
- Fire bisque slowly up to 1000 degrees Centigrade. Stack pots rim up. Do not stack pots inside or on top of each other.
- Shrinkage is high and, therefore, any temperature gradient causes warpage. High iron content causes excess shrinkage where reduction occurs or where flames touch. High iron content can also cause bloating.

To prevent excess shrinking or warping:

- Shape must be structurally sound.
- Maintain a clean, even firing cycle (oxidation only).
- Protect pots from flame.

With a slow, clean firing, most tropical clays fire to a reasonable hardness and can be glazed successfully. It is very difficult to reduce absorption below 5 to 10 percent without causing slumping.

Thermal shock resistance of tropical clays is good to excellent. With sand or grog added, most tropical clays can be brush- or pit-fired (approximately 800 degrees Centigrade) without excessive loss. The resulting pottery is rather soft and, therefore, works well as cook pots or on an open fire. Brush-fired clay does not travel well, due to its fragility, but works for stove linings, water filters, cook pots, small decorative items, bricks, etc. If the firing temperature is too low (under 700 degrees Centigrade), the fired pot will eventually crumble if exposed to water.

When fired at over 1000 degrees Centigrade, most of the clays become much more durable. A 1000 degrees Centigrade fire is a bright red orange color. To reach 1000 degrees Centigrade or over, it is necessary to construct a kiln to contain the heat.

Excessive shrinkage can be reduced by adding as much silica sand or grog as can be added and still use the clay. Maturing temperature, plasticity, and absorption can be changed by blending with other clays. For example, to lower absorption, add a clay with a lower maturing point, talc, feldspar, or ground glass. To increase plasticity, age as long as possible (minimum one week), blend with more plastic clay, or add a small amount of bentonite. Bentonite is mostly Montmoillonite and is highly plastic. Do not use over 5 percent. To decrease plasticity, blend with a short clay or add sand or grog; this also helps to prevent cracking.

Never use beach sand. It is calcium carbonate and turns to lime in the heat. This will destroy the pot. Instead, use silica sand, river sand or any inland deposit not associated with the ocean, shells, or coral.

Grog is ground up, fired clay, usually broken pots from the fire. Never use glazed pieces. To make grog, crush broken pieces of pot in a yacona pounder or with a hammer or a stone. Sift the crushed pieces through a fine screen. Remove any piece left in the screen, crush again, and rescreen. Grog that passes through the screen can have fine dust removed, if necessary. Too much dust sometimes causes cracks in the finished pot. If it causes no trouble, leave it in and do not worry. To remove the dust, winnow as you would remove chaff from rice. In a windy open area, pour grog from one container to another, as shown in Figure 8, allowing wind to blow dust away. Any larger particles stay. Repeat this two or three times.



Figure 8. Removing Dust from Grog

### III. LOCATING AND EVALUATING CLAY

In the tropics and on islands with a volcanic history, clay deposits are younger, smaller, and often part of the original rock. They also occur in river deltas and low areas. There are many clay deposits on hillsides that are the result of the weathering of a rock mass; thus you will often find clay from the bottom to middle of low hills, as shown in Figure 9.

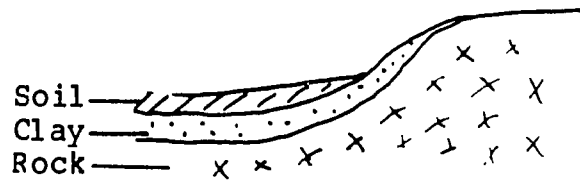


Figure 9. Where To Find Clay Deposits

Low lying areas, especially if water does not drain easily, probably have clay under 1-4 feet of peat or muck. Sometimes a field will have several feet of clay 1-2 feet below the top soil. River and stream banks often show clay deposits under 1-2 feet of soil. Sometimes a deposit of sand occurs close to the water, so try digging about 20 feet from the water. Roads and irrigation ditches often cut through clay deposits, giving easy access to the material. Clay is easily recognizable when wet because it is slick and shiny and has water puddles on it. When it dries, clay cracks and has a hard smooth surface, as shown in Figure 10.

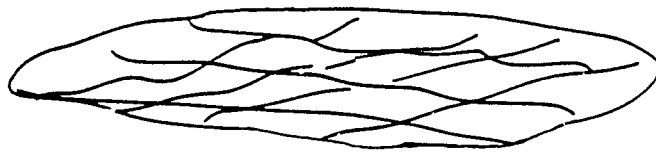


Figure 10. Recognizing Dry Clay Deposits



Banks erode in rivulets, not smoothly, and fine clay is carried down to the bottom where it cracks and curls when dry, as shown in Figure 11.

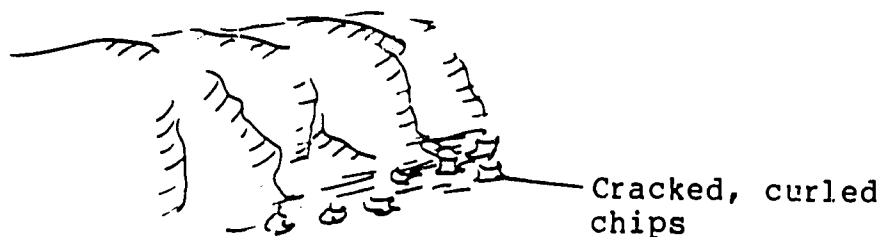


Figure 11. Recognizing Clay Deposits at the Bottom of Banks

Two simple field tests will help to establish whether a deposit is actually clay. The only true test is in the fire, but a lot of non-clay material can be discarded by performing these tests:

First, moisten a lump of test material and knead it until it is free of large lumps and the consistency of putty or bread dough. Squeeze an egg-sized piece in one hand, as shown in Figure 12. If the lump holds together, does not crumble, and retains the clear impression of your hand, as shown in Figure 12, it may be clay.



Figure 12. Clay Test No. 1

Second, take another small piece of the kneaded material and roll out a pencil-sized coil. Bend this around one finger. If it bends without cracking or only cracks slightly, as shown in Figure 13, it may be clay.

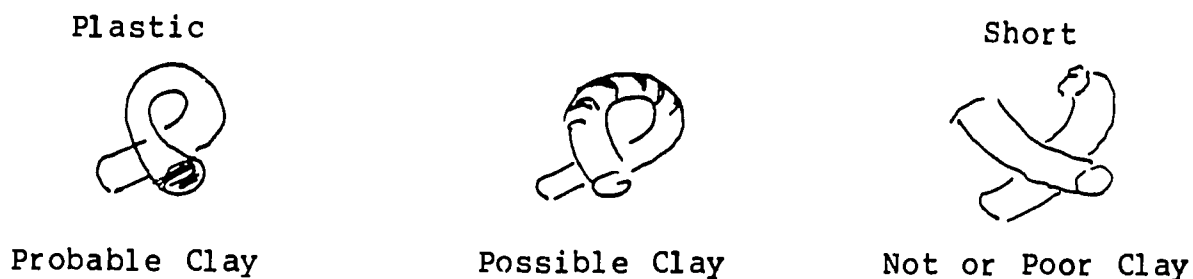


Figure 13. Clay Test No. 2

#### IV. PROCESSING CLAY

The materials you will need to process clay include a shovel, a piece of window screen mounted on a frame, two or three pails or other large containers, several pieces of cloth (cotton sheeting or muslin) and plastic bags.

Build a 1 foot x 1 foot frame out of 2 inch x 2 inch lumber or 1 inch x 2 inch lumber, as shown in Figure 14.

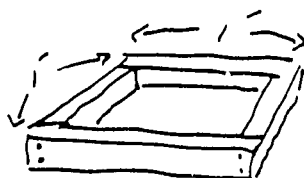


Figure 14. Building the Frame

Firmly tack the window screen on one side of the frame so there are no gaps, as shown in Figure 15.

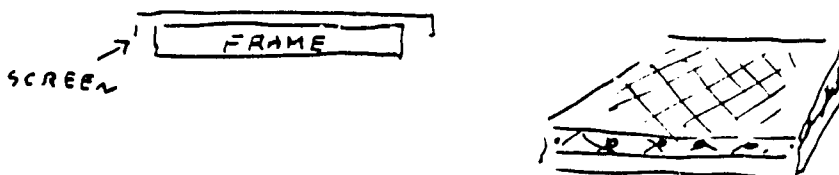


Figure 15. Nailing the Window Screen onto the Frame

You are now ready to make clay in quantity. Remember that the longer it can sit in the plastic state, the better it will be when you use it. Follow these instructions:

1. Break up lumps to golf ball size or smaller and spread out to dry. If collecting large quantities, store in bulk and spread to dry as needed.
2. When clay is completely dry, put it into water to slake. Use a 44-gallon drum or large pail half filled with water. Clay should not be above water.
3. Let stand without stirring until the clay softens. This can vary from a few hours to a few days, depending on the clay.

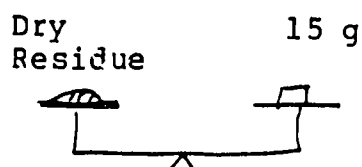
4. Stir vigorously with a paddle or by hand, adding water as necessary, until the clay is the consistency of thin cream. The clay is now slip.
5. Dip out slip and screen through a window screen or a 30-mesh sieve. This depends on clay and tooth desired.
6. Some clays will settle readily at this consistency, if allowed to stand for several hours. This leaves clear water on top which may then be siphoned or poured off to make drying easier.

## MIXING CLAYS

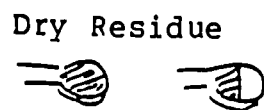
Clays can be mixed before processing or after they are made into slip. Use the following procedure to mix before processing: If the clay contains a high proportion of rock fragments or other large non-clay particles, and you wish to blend it with other clays, it helps to know the amount of material that will be removed by the screening. Suppose you want to blend two clays, A and B. Assume Clay A has 20 percent residue and Clay B has 5 percent residue. You can blend the two clays before processing (which is much easier) by adding 20 percent extra of Clay A and 5 percent extra of Clay B to whatever blend you are making. After making slip and screening, the proper proportions of the blend will result.

To determine the amount of non-clay residue, follow these steps:

1. Weigh out 100 grams of dried clay or measure out by volume, 10 small measures (such as spoonfuls).
2. Add weighed or measured amount of dry clay to water in a container. Water should cover clay fully. Allow to slake from 1 to 24 hours, depending on how quickly the clay breaks down in the water. When slaked, stir until no lumps remain. Add water, if needed, until consistency of cream is reached.
3. Pour through a screen into a second container. Dry residue (what is left in screen). Extra water may be poured over residue in screen to wash away any clay remaining.
4. Weigh or measure residue, as shown in Figure 16.



Percent of Residue =  
 Weight in Grams  
 15 Percent Residue



1-1/2 Measure

10 Measures = 100 units  
 1 Measure = 10 units  
 1 1/2 Measures = 15 units  
 Percent Residue = Number of Units  
 15 Percent Residue

Figure 16. Weighing or Measuring Residue

To mix clays after they are made into slip, you must know the dry weight of the materials in a known amount of slip. The dry weight of ingredients can be calculated using the following formula:

$$W = \frac{P - 20(g)}{g - 1}$$

where:

W = the dry weight needed  
 P = the weight in ounces of one pint of slip  
 g = the specific gravity of the solid  
 20 = the weight in ounces of one pint of water.

The specific gravity of pure water is about 1.  
 The specific gravity of clay is about 2.6.  
 The specific gravity of potash spar is about 2.56.  
 The specific gravity of flint (silica) is about 2.65.

If two or more local clays are to be mixed as slips, determine the correct proportion by the above formula. It is not necessary to return the slips to the mixer, just stir them to assure a mixed batch.

When adding dry ingredients such as feldspar, determine dry weight of clay in the slip. Start with a small amount of water. Add a known amount of the slip. Then, slowly add other dry ingredients as needed to complete the correct proportion. Add water, as needed, to retain slip consistency. When mixed, dip out and allow to settle. It should not be necessary to screen at this point.

Which ever method is used, you should now have a slip that contains all of the desired ingredients, including grog, if called for.

## DRYING CLAY SLIP

There are several popular methods of drying clay slip: (1) plaster bats; (2) clay bats; (3) drying clay with bricks; (4) drying clay in a cloth bag; (5) drying clay with cloth and sand; and (6) drying clay in a frame.

### Plaster Bats

Make large plaster bats over a lump of plastic clay approximately 12 to 18 inches by 24 to 30 inches by 4 to 6 inches. Use strips of burlap dipped in plaster to strengthen and make wall approximately 1 inch thick. See Figure 17. Fill with clay slip.

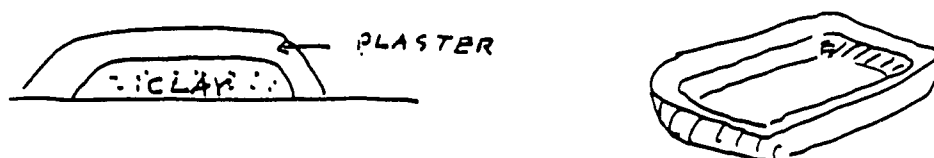


Figure 17. Making a Plaster Bat

Several bats will be needed as they must be dried after each use. It takes two days or more to dry the clay. Bats take considerably longer to dry unless a kiln is running.

### Clay Bats

Clay bats can be made and bisque-fired at a low temperature, if a good porous body is available. They should be smaller than the plaster ones and fired no higher than 900 degrees Centigrade. They work quite well and have the advantage of not contaminating the clay with non-clay materials. See Figure 18. Large bisque-fired clay bowls can also be used, provided they are at least an inch thick.



Figure 18. Making a Clay Bat

### Drying Clay with Bricks

Using low-fired commercial brick or homemade ones, build a floor raised on bricks, set crosswise to give air circulation underneath. Set other bricks at the edges to contain the clay and pour slip inside. Cover with other bricks so drying is even. See Figure 19.

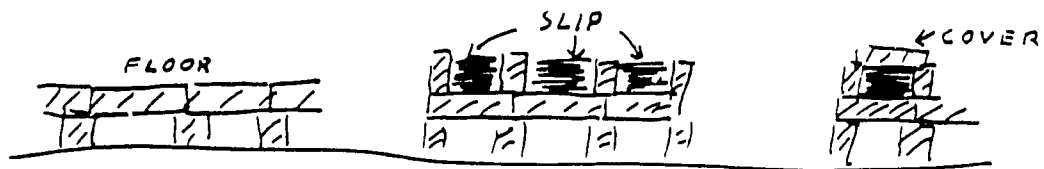


Figure 19. Drying Clay with Bricks

### Drying Clay in a Cloth Bag

As shown in Figure 20, make a bag big enough to hold a basketball out of thin canvas or sheeting; fill with slip and tie up the open end with a rope. Hang where water can drip out. This method is quite effective but often uneven, leaving dry edges and liquid centers. Combined with bats, it works well, since much of the water can be removed before putting in the bats.



Figure 20. Drying Clay in a Cloth Bag

### Drying Clay with Cloth and Sand

As shown in Figure 21, scoop a shallow hole in dry sand and lay the cloth in it. Fill the hollow with slip. In a dry area and on a dry day this works quite well. It takes from one to three days to dry to a plastic consistency.

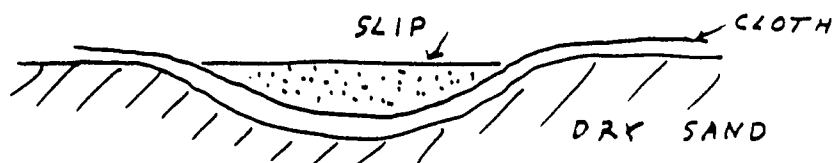


Figure 21. Drying Clay with Cloth and Sand

## Drying Clay in a Frame

As shown in Figure 22, make a 2 foot square out of 2 inch by 2 inch wood. Cover one side with cloth and then wire mesh, such as chicken wire, to keep the cloth from sagging. Make a rack or arrange bricks to hold up the edges of the frame so cloth does not touch. Water drips out and if watched for uneven drying, this works quite well. Store plastic clay in airtight plastic bags or plastic garbage cans. The longer, the better, since clay improves with



Figure 22. Drying Clay in a Frame

## CLAY MIXERS

If a mechanical mixer is available, set it up in a separate drum and add water to cover blade. Start mixer in water and add slip clay slowly with additional water as needed to make a thin, creamy consistency. Mix until lumps are gone. Once mixer is started, do not stop and restart, as the lumpy slip can cause the motor to burn out. Strength of the motor will determine the amount of clay you are able to mix at one time. One-half horsepower will mix about one-third ( $1/3$ ) of a drum, if used with caution so as not to overload. A typical clay mixer is shown in Figure 23.

Warning: Do not stop and restart mixer in slip; start only in water. Therefore, mixing, once started, should be completed before shutting off mixer.

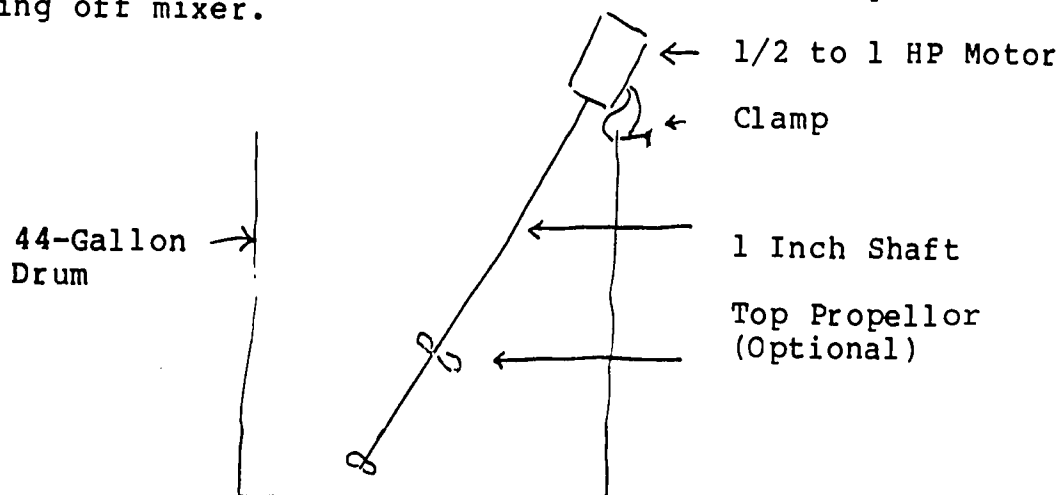


Figure 23. A Clay Mixer

If a mixer is to be built, use a shaft length and clamp to fit container to be used. The motor should be 1/2 to 1 horsepower. Use a 3-inch propellor made out of 1/4 by 1-1/2-inch stainless steel welded to the shaft. Balance is most important to reduce vibration. Set the top blade so the clay is lifted and the bottom blade so the clay is forced down. The propellor may have two, three, or four blades.



## GLOSSARY

Absorption	Sucking in of fluid (water retention) due to porosity.
Adsorption	Attraction of liquid molecules to the surface of a solid; electrical bonding.
Alumina	Oxide of Aluminum $Al_2O_3$ .
Basalt (Basaltic)	Dark igneous rock of volcanic origin and contains iron.
Bats	Large, shallow, porous containers.
Bisque (biscuit)	Clay that has been fired once or the first firing itself.
Chemical	Combination of elements into new substances or the reverse; molecules from atoms or atoms from molecules.
Clay	Alteration product of igneous rock, hydrous silicate of alumina $Al_2O_3 \cdot SiO_2 \cdot 2H_2O$ .
Feldspar	Mineral composed of alumina, silica and either potassium, sodium or calcium, for example: $K_2O/Al_2O_3/6SiO_2$ is called Potash Feldspar.
Feldspathic Rock	Rock composed primarily of feldspar.
Flux	Any substance that lowers the melting point of the mix.
Glaze	A controlled glass bonded to the surface of a ceramic piece.
Grog	Crushed, fired clay.
Ground Glass	Powdered glass, such as bottles crushed to a powder.
Halloysite	Disordered Kaolin particles often tubular in form.
Illite	Clay mineral.
Kaolin	Clay mineral $Al_2O_3/2SiO_2/2H_2O$ .

Kiln	Refractory containers for heating ceramic ware.
Maturing Temperature	The temperature at which the clay obtains optimum hardness and durability without melting.
Mineral	Inorganic substance.
Molecule	The smallest grouping of atoms to which a substance can be reduced without losing its chemical identity.
Montmorillonite	Clay mineral capable of both absorption and adsorption of water.
Oxidation	Conditions of burning (kiln firing) with an excess of oxygen.
Parent Rock	Original rock from which a clay is weathered.
Plaster (plaster of Paris)	Calcined and ground gypsum (calcium sulphate).
Plasticity	Ability to bend without cracking.
Porous	Able to absorb liquid.
Primary Clay	Clay weathered in place and not transported by water.
Reduction	Conditions of burning (kiln firing) with a lack of oxygen atmosphere of free carbon or CO or CO <sub>2</sub> .
Secondary Clay	Clay transported in water.
Short	The opposite of plastic; cracks on bending.
Silica	Oxide of silicon SiO <sub>2</sub> ; also known as quartz or flint.
Silica Sand	Particles of quartz or SiO <sub>2</sub> .
Slake	The absorption of water by clay to make a slip.
Slip	Watery clay thin enough to pour.
Slump	Sagging or deformed from its own weight.

Talc	Mineral containing silica; used as a body flux.
Temperate Zone	Middle latitudes of the northern and southern hemispheres.
Thermal Shock	Reaction to suddenly applied heat such as open flame or sudden chill.
Tooth	The amount and character of grit in the clay.
Weathering	Action on a substance by natural forces, such as rain, wind, freezing, and sun.

## SUGGESTED READING LIST

- Buchanan, W. Hand Moulded Burnt Clay Bricks: Labour Intensive Production. Malawi Ministry of Trade, Industry, and Tourism (United Nations Industrial Development Organisation, Project DP/MLW/78/003), undated.
- Cardew, M. Pioneer Pottery. New York: St. Martin's Press, 1976.
- Green, D. Pottery Glazes. New York: Watson Guptill Publishing, 1973.
- Leach, B. A Potter's Book. Hollywood, Florida: Transatlantic Arts, Inc., 1967.
- Parry, J.P. Brickmaking in Developing Countries. Prepared for Overseas Division, Building Research Establishment, UK. Garston, Watford, United Kingdom: Building Research Establishment, 1979.
- University of California. Division of Agricultural Sciences. California Agricultural Experiment Station Extension Service. Adobe Construction Methods. Manual 19 (Revised). 1964.

B